Electronics I. laboratory measurement guide

FET characteristics, amplifiers, inverters

2025

In this measurement we are going to measure a JFET's characteristics and build an amplifier using it, measure MOSFET characteristics and build a CMOS inverter. In the first measurement we'll need two power supplies. Set up about 20mA current limit on both.

3.1 N-channel JFET characteristics

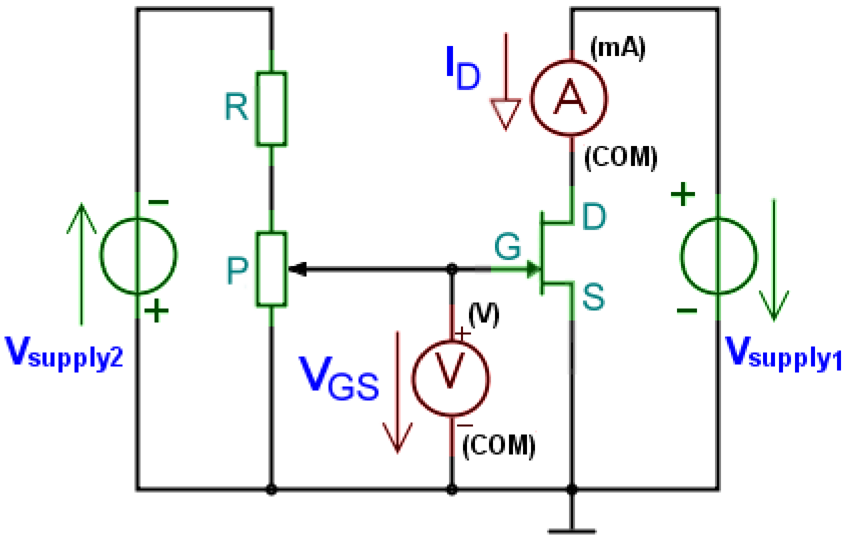

Figure 3.1 : Measuring J211A n-JFET characteristics

3.1.1 Build the circuit seen on figure 3.1.
Be careful with the power supplies: the $V_{supply2}$ is connected such as to give negative potential to the gate (don't connect positive V_{GS} , it can damage the n-JFET!).
The voltmeter will measure the $\mathbf{V_{GS}}$ (which thus **has to be negative**), the ampermeter will measure the drain current (use 3 digits precision on both).
Potentiometer P=1kΩ is used to change the gate-source voltage (using a screw driver).
$V_{supply1}$=15V ; $V_{supply2}$=5V ; R=300Ω.

3.1.2 Measure the transfer characteristics of the JFET (V_{GS}-I_D, V_{DS}=constant).
First, find the pinch-off (or treshold) voltage V_0 (where I_D is approximately zero) and the maximum drain current I_{DSS} (where V_{GS}=0). Then measure the characteristics between these points in at least 10-15 points!

3.1.3 Measure the output characteristics for a constant gate-source voltage (V_{DS}-I_D, V_{GS}=constant)! Choose V_{GS} such that the drain current is about I_D=I_{DSS}/2. Note this V_{GS} and keep it constant for this measurement. Choose V_{DS} values (which is practically equal to $V_{supply1}$) from 0 to 20V in about 20 points (choose them more densely in the rising part of the characteristics.

3.2 Common-source JFET amplifier

3.2.1 Build the amplifier circuit seen on figure 3.2. Data: $R_L=R_D=5.1k\Omega$; $R_G=1M\Omega$; $R_S=2,2k\Omega$ (potentiometer). $C_1=C_2=100nF$; $C_S=47\mu F$, $V_{supply}=15V$.

Use the same JFET that you measured in the previous exercise. Its measured I_{DSS} and V_0 values will be needed for the calculation in this exercise. If you don't have the same JFET, make sure to measure the I_{DSS} and V_0 values first before doing the amplifier.

For the lab report, calculate the operating point and the voltage gain using the aforementioned measured parameters and the fact that here we set $V_D=V_{supply}/2$.

Do not connect the function generator nor oscilloscope on the inputs and outputs yet.

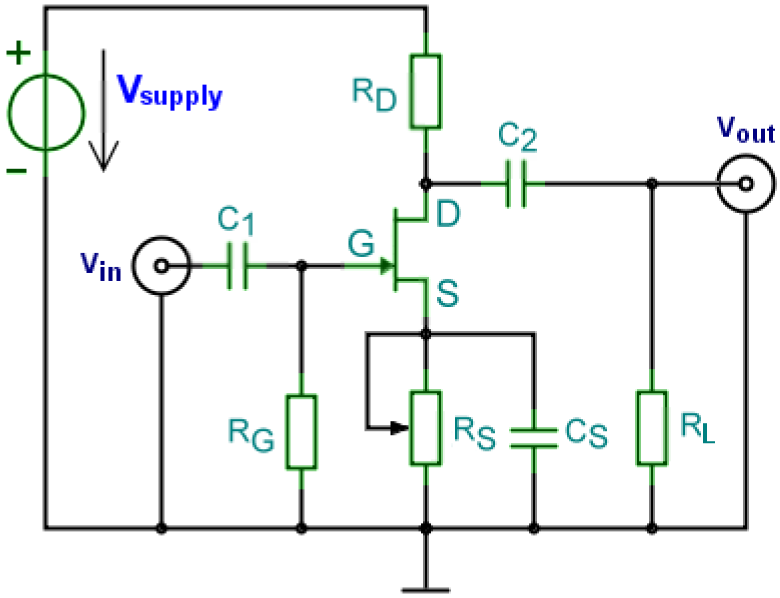

Figure 3.2: Common source JFET amplifier

3.2.2 Measurement of the operating point parameters. Setup the potmeter R_S such that V_D is equal to half of the power supply voltage ($V_D=V_{supply}/2$). (The potmeter is needed because the JFET's parameters have a large manufacturing tolerance, thus we can't design the circuit with precise resistor values). After setting up the potmeter, take it out of the circuit, measure and note its resistance, then put it back into the circuit. Measure V_S. Calculate the drain current I_D and the expected gain A_V. How much is V_G and why?

3.2.3 Connect the point V_{in} to the analog output of the function generator and also to channel 1 of the oscilloscope (use a BNC-BNC T-junction and BNC-BNC cables). Connect V_{out} to channel 2 of oscilloscope.

Setup an f=5kHz, 500mV peak-to-peak sine wave output on the function generator. Draw and measure the input and output signals, including p-p values, phases, frequency/period. Measure the voltage gain (convert to dB as well) and compare with the calculated value.

3.2.4 Remove capacitor C_S and measure the gain.

3.2.5 Measure the lower and higher limit frequencies! Put back the C_S capacitor into the circuit. Change the function generator's frequency (in both directions) until the output signal's p-p value is about 70% of the original (this is the -3dB point). These will be the limit frequencies.

3.3 Transfer characteristics of n-channel enhancement MOSFET

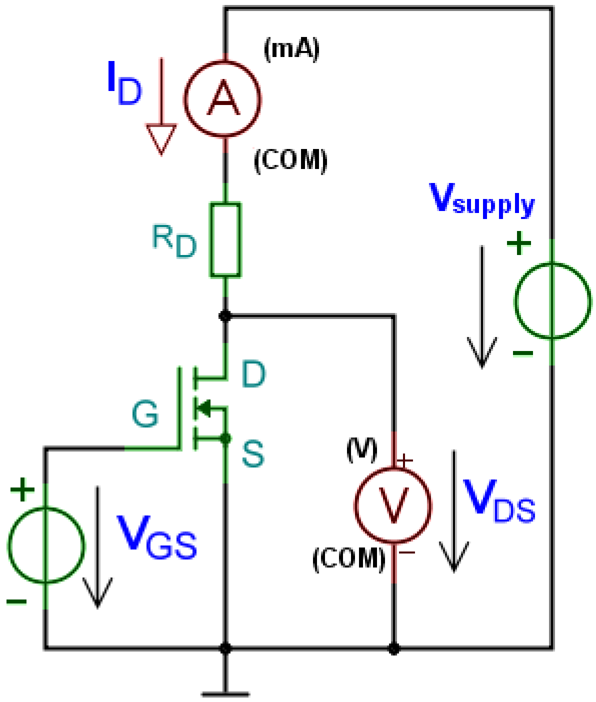

Figure 3.3: measuring n-channel MOSFET characteristics

3.3.1 Build the circuit of figure 3.3 to measure BS170 n-channel enhancement MOSFET's transfer characteristics (V_{GS}-I_D, V_{DS}=constant). Setup 3 digits of precision on the ampermeter and the voltmeter. R_D=180Ω (P_{RDmax}=5W).

Setup a current limit of 100mA on V_{supply} (which will be first 5V, then 10V) for this exercise.

3.3.2 Setup V_{supply}=5V. Measure the transfer characteristics (ie. V_{GS} vs I_D) by changing V_{GS} between 0..5V. Make one measurement point at least every 0.5 volts, but make sure to measure more points in the range where the current increases quickly (approx. between 2.0 and 2.5 volts).

When V_{GS}=5V, measure V_{DS}, and calculate $R_{DSON}=V_{DSon}/I_{Don}$ ("on" meaning the FET is turned on as much as possible). Compare it with datasheet value!

3.3.3 Repeat the previous measurement with V_{supply}=10V.
In the lab report, compare the characteristics you measured with the theoretical expectations. If there are differences, what may be the reason?

Change the current limit back to 20mA before doing further exercises.

3.4 CMOS inverter

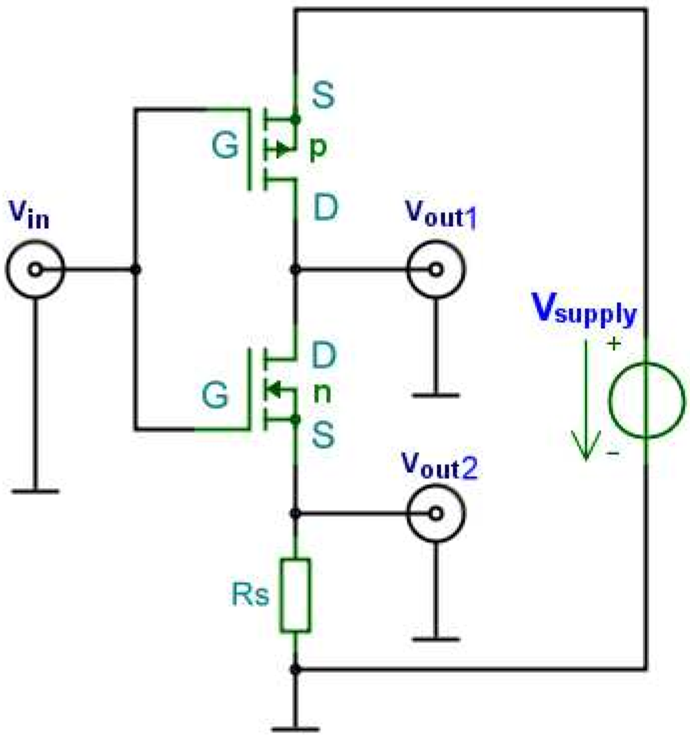

Figure 3.4: CMOS inverter

3.4.1 Build a complementary MOS inverter as seen on figure 3.4. The n-MOS is the BS-170 from the previous measurement, the p-MOS is BS250. R_S=13Ω. V_{supply}=5V. Connect the TTL output of the function generator to V_{in}, also to oscilloscope channel 1 (using the T-junction again). Connect V_{out1} to channel 2.
(Note: the real CMOS inverter has only one output, R_s and V_{out2} are not there. These are here only because we want to measure the current.)

3.4.2 Setup a square or pulse waveform on the function generator with voltage levels of 0V and 5V. (On the Hameg function generator, use the "TTL" output, it's already at those values. On the Rigol, select Square or Pulse waveform and press the Amplitude button twice so it displays HiLevel and LoLevel. Set LoLevel to 0V and HiLevel to 5V.) Try the circuit at frequencies of 1kHz and 100kHz as well.
Measure and draw the input and output signals with proper phases; show that it is an inverter.

3.4.3 Connect channel 2 (or channel 3) to V_{out2}, thus measuring the voltage on R_S. The signal is expected to be in the mV range!
Draw the signals V_{in} and V_{out2} with proper phases and explain what you see!
What is the meaning and importance of V_{out2}?

3.5 Test questions

1. Draw the transfer and output characteristics of a n-JFET in common source mode. Note the parameter for the output curves. Note the special points.
2. Draw the transfer and output characteristics of an enhancement mode n-MOSFET!
3. Draw a common source n-JFET amplifier circuit. Name the components.
4. Write down the equation of the transfer characteristics of the JFET and explain the parameters.
5. What is the RDSon parameter of MOSFETs? What is its use / importance?
6. Draw the circuit symbols of n- and p-channel JFETs, enhancement and depletion mode MOSFETs! Name the pins!
7. Define the concept of slope (transfer conductance) and give the equation of it for the JFET!
8. Define the concept of lower and upper limit frequencies (in words and with graphs).
9. What do you know about the gate current of MOSFETs in low frequency and high frequency?
10. How much is the input resistance of a CS JFET amplifier?
11. What is the output resistance of a CS JFET amplifier?
12. What does CMOS mean and how does a CMOS inverter work?
13. What causes the non-zero current consumption of a CMOS inverter even when the load is open-circuit?
14. Give the temperature dependence of a JFET's transfer characteristics using graphs.
15. Why is a JFET amplifier's voltage gain much smaller than that of a bipolar transistor amplifier?